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Service Paper

TWO SOURCE UNITS IN ASTRONOMY

Submitted by

Harry Clement Stubbs

(B. S., Harvard, 1943)

In partial fulfillment of requirements for

the degree of Master of Education

1947

First Reader: Dr. Roy O. Billett, Professor of Education

Second Reader: Mr. Edward J. Eaton, Professor of Education

Boston University
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CHAPTER I

ASTRONOMY IN THE GENERAL SCIENCE COURSE

Purpose and Scope of the Paper

Purpose.-- The purpose of the present paper is to assist teachers of general science in planning the astronomy units[1] of their courses by means of two source units; that is, units designed to provide material useful to teachers in a variety of situations rather than to deal with a specific school, time, and class. The problem faced in undertaking this task is substantially that of the individual teacher: to design one or more units in astronomy which do not require an excessively long time to teach, and which can be fitted into the general science course with a minimum of teacher and pupil confusion and a maximum of usable content matter.[2] The principal exceptions to this statement are that the writer of the source unit cannot envision a particular class and work toward its needs, while he must provide much more extensive reference material than the individual teacher if he expects his work to be useful.

1/ Roy O. Billett, Fundamentals of Secondary School Teaching, p. 505.

2/ Thirty-first Yearbook, National Society for the Study of Education, p. 255.

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Scope.-- The present paper contains two units, "The Earth in Space," which deals with the structure of the Solar system and universe as understood at present by astronomers, and "The Clock Beneath our Feet," dealing with the measurement of time and the relationship between time and longitude. The complete navigation problem is not included; the determination of latitude and solution of dead reckoning problems, although frequently included in sections on astronomy both in course work and text books, bear only the slightest relationship to the time-longitude problem, which is the subject of the second unit.

Methods.-- In preparing this paper the units were first stated, and their delimitations[1] written; unit assignments[2] were then prepared, involving activities which the writer felt would contribute to the desired objectives; and finally, reference material was sought which would provide both teacher and pupil with the information necessary to plan and carry out these activities. This last phase was the most laborious and, in the writer's opinion, the most important, as the activities and even the unit delimitations may be modified to suit particular situations by the teacher using the material, while the references must be made to cover the greatest possible number of situations. Most of the material

1/ Roy O. Billett, op. cit., p. 505.

2/ Ibid., p. 506.

was obtained from the Children's Room of the Cambridge Public Library, Cambridge, Mass.; Widener Library, Harvard University; and the Library of the Harvard College Observatory. In each case, the material considered by the writer to be most suitable to the present purpose was selected. No general science texts are included, though these may also be found useful.

Justification for the Study of Astronomy

The Earliest Observations.-- Men have been wondering about the stars since long before they invented writing. The Chaldean shepherds possessed a body of star-based mythology which must even in their time have been many generations in growing; the men of Babylon and Greece, Egypt and India and China had all noticed the little points of light in the night sky and tried to explain them. Very early in history, some of the wisest men learned a few of the empirical laws which make possible the prediction of the motions of the more prominent celestial bodies. The saros, or 223-month eclipse cycle, was known to the Chaldean priests well over three thousand years ago.

Early man's reaction.-- It was perhaps natural to ascribe to these mysterious objects, which circled serenely above the heads of the early men serenely untroubled by the events which seemed so cataclysmic to humanity, the power of directing human destiny. It was, indeed, this belief which

motivated much of the early study of the heavens; and astrology was well developed long before the time of Christ. A glance at a modern news stand will show clearly that it still exists; there are quite enough people constantly on the search for something to take from their shoulders the burden of making decisions, and on which they can lay the blame for their own errors, to provide excellent incomes for quite a number of professional astrologers.

More modern attitudes.-- Man's progress in the physical sciences during the last few centuries has tended, at least in the minds of most well-educated persons, to rob the heavenly bodies of their personal connection with human destiny; but the influence of the stars and planets, the galaxies and gaseous nebulae, on our understanding of the physical universe is certainly no less miraculous. The first tests of Newton's laws of motion and gravitation were made by observing the correspondence between the actual motions of the moon and those predicted with the aid of the new "Laws." The more general conclusions of the theory of relativity were also checked astronomically, from the changes in the orbit of Mercury, the gravitational deflection of light rays passing close to the sun, and the loss of energy of light quanta escaping from the dense gravitational field of Sirius B. Our knowledge of the structure of matter and the behavior of energy has stemmed at least as much from the

observatory as from the physics laboratory; for many phenomena which with our present technological abilities we cannot reproduce on the earth are everyday, and every second, occurrences in the vast furnaces of the stars and the vaster voids between them. In those extremes of heat and cold, pressure and vacuum, darkness and intense radiation, secrets of nature which are hopelessly unattainable under terrestrial conditions lie open to investigation by the instruments of the astronomer.

In the sixteenth century a "natural scientist" could and did know most of what there was to be known about astronomy, physics, chemistry, geology, and the few other organized sciences that could be said to exist; by the close of the nineteenth century the sciences had become so walled off from each other that the chemist and astronomer almost talked different languages, and a famous astronomer could publish without ridicule a theory which suggested that only the visible surface of the sun was hot, while the rest was habitable; he knew astronomy, but no physics. Now, while no one man can learn all the sciences, the barriers have once more broken down, and the astronomer must know some physics, the physicist some chemistry, and the chemist some geology in order to make progress in his chosen field. One of the foremost authorities today on problems connected with the sun earned his doctor's degree in chemistry; on one occasion the writer,

taking courses in astronomy, physics, and geology, found himself using identical formulae in the assignments of all three courses.

A similar connection exists between the physical sciences in general and the other fields of human endeavor, and those whose professions are not directly scientific in nature cannot afford to be totally ignorant of science. Understanding the earth's place in the universe, and the nature of the universe itself, are not merely emotional satisfactions; such knowledge is part of a mental background vitally necessary to anyone who wishes to react intelligently to events in an environment which has been so completely remolded as a result of man's persistent inquiry into the nature of all that goes on about him.[1/]

Science, therefore, forms a necessary part of education; and astronomy should take its place among the sciences taught, if only to inculcate an understanding of the interdependence of all fields of knowledge.

No secondary school, however, can be expected to devote a very large part of its curriculum to the study of astronomy; and in consequence, the teacher is faced with the problem stated in the first paragraph of the present paper.[2/]

1/ Thirty-first Yearbook, National Society for the Study of Education, pp. 27-30.

2/ Ibid., pp. 209-211.

CHAPTER II

THE FIRST UNIT: THE EARTH IN SPACE

The Unit

General statement of the unit.-- The earth on which we live forms a tiny part of a vast universe which exists under the control of many, definite laws. Men have learned many of these laws, and from them can predict the future behavior of celestial objects, as well as learn much of their nature.

Delimitation.-- The following items are arranged in logical but not necessarily pedagogical sequence:

1. The earth is a globular body moving in space.
   a. At any point on its surface, "down" is toward the center of the globe.
   b. The globe turns on an imaginary axis once each day; the resultant carrying of each point on its surface alternately toward and away from the sun results in alternating day and night.
2. The earth travels around the sun in a nearly circular path once each year.
   a. The centrifugal force produced by this motion just balances the attracting force which exists between sun and earth.

3. The sun is a great, spherical mass containing most if not all of the substances found on the earth.
   a. The sun is at such a high temperature that all these substances exist in a gaseous state.
   b. Because of its high temperature, the sun is constantly emitting light and heat.
4. The moon travels around the earth once a month, much as the earth travels around the sun each year.
   a. The moon is a cold, solid body like the earth, not hot and shining like the sun.
   b. The moon is visible to us only because the light from the sun illuminates it.
5. Certain other bodies, called planets, also move around the sun, in paths of their own.
   a. Many of the planets are in turn attended by moons.
   b. The earth is a planet.
6. The planets are solid bodies, very cold when compared with the sun.
   a. The planets are visible to us only because they are illuminated by sunlight. The same is true of their moons.
7. There are nine known planets circling the sun. In order of increasing distance from the sun they are: Mercury, Venus, the earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.

8. The planets vary in size. In order of decreasing size they are: Jupiter, Saturn, Uranus, Neptune, the earth, Venus, Mars, and Mercury.

   a. The size of Pluto has not been accurately determined, because of its great distance from us, but is probably not greatly different from that of the earth.

9. The physical conditions on the planets differ greatly.

   a. Mercury and Venus, being closer to the sun, are hotter than the earth.

   b. The other planets, being farther from the sun, are colder than the earth; some are very cold indeed.

   c. Some planets, like Mercury, have no air; others, like Mars, only a little.

   d. On some of the planets, such as Jupiter, the air differs chemically from that of the earth.

10. Many bodies, ranging in size from very small planets to objects only a few yards across, also travel about the sun. These are known as planetoids or asteroids.

11. Still smaller objects, known as meteors, also circle the sun. These are ordinarily invisible.

    a. When a meteor chances to enter the earth's air envelope, it is rendered incandescent by compression of the air ahead of it, and thus becomes visible.

b. Most such meteors are completely boiled away before reaching the ground.

c. Meteors occasionally do reach the ground if sufficiently large or slow-moving; these are called meteorites.

12. Objects known as comets also travel, frequently in very peculiar paths, around the sun. Little is known of their composition, except that they are largely gaseous.

a. Comets are usually visible only in the section of their paths lying nearest to the sun.

b. Comets frequently exhibit long, streamer-like tails of gas, which appear to be pushed out from their main substance by the pressure of sunlight, as they always point away from the sun no matter which way the comet is travelling.

13. The sun and its family of planets, their satellites, the planetoids, meteors, and comets, all make up the solar system.

14. The stars are hot, glowing bodies similar in structure to the sun.

a. The sun is a fairly typical star.

b. The stars lie at such vast distances that they are visible only as points of light.

c. Some or all of the stars may be centers of solar

systems, but their great distance makes it impossible in most cases to discover any trace of their attendants.

15. The vast majority of the stars appear to lie in a fairly narrow, rather irregular zone extending entirely around the sky, known as the Milky Way.
    a. The appearance of the Milky Way can be accounted for by supposing that the stars are actually arranged in a vast, roughly disc-shaped group, with the solar system lying within its limits.

16. Other disc-shaped and pinwheel-shaped groups of stars have been observed by the hundred thousand, lying apparently beyond the confines of the Milky Way and extending as far as our telescopes can reach. These clusters of stars are known as galaxies; and the Milky Way system is believed to be a similar galaxy.

The Unit Assignment

Introduction.-- Introductory material is designed to arouse pupil interest in the unit.

1. The pupils are shown a picture of the earth as it is believed to appear from space, either by passing around a magazine containing such a picture[1/] or, preferably with the

1/ An excellent series of astronomical paintings appears in the National Geographic Magazine, July, 1939. The accompanying article is also very satisfactory school-level material.

aid of the opaque projector, while discussion is started concerning what the pupils already know of the earth as a spherical object moving in empty space. The picture should be kept before the pupils during as much of this discussion as possible, to fix in their minds the concept of the earth's unattached state. The ordinary classroom globe will not be adequate for this purpose, since it is always mounted on a clearly visible support.

If such illustrative material cannot be obtained, the pupils may be asked to make sketches of their own on the same subject-- the earth as seen from space. The best of these may be selected and commented upon, care being taken to bring out the concept stressed above.

2. Other astronomical pictures, either paintings or photographs, should be displayed on the bulletin boards for a few days preceding the opening of the unit. The display may be arranged either by the teacher or by pupils with suggestions from the teacher.1/

3. If the teacher deems it necessary or desirable, the elementary facts usually given in geography texts as proofs that the earth is spherical may be reviewed at this point.

The body of the assignment.-- The unmarked items in the

1/ An excellent series of astronomical paintings appeared in the National Geographic Magazine, July, 1939. The accompanying article is also very satisfactory school-level material.

following list represent activities such as would be conducted in class either by the teacher himself or under his direct supervision; the items marked with an asterisk are such as would appear on a pupil's mimeographed study guide.

*1. Read at least two of the following, then write a two-page composition describing the Solar System in your own words. (References given in available books, from sections describing structure and make-up of the Solar System, such as 1, Chaps. I-IV: 2, Chaps. II-VI: 11, Chaps. II-VI: 12, Chaps. I-IV; 14, pp. 115-123; 18, Chap. I, Chaps. IV-X; 19, Chaps. 17-32; 20, entire book.)

2. Hold a class demonstration of centrifugal force; a small object such as an eraser swung on the end of a string or a rubber band of the type used to power model airplanes may be used to illustrate the balance of forces; the more spectacular swinging of a container of water overhead will make it amply clear that centrifugal force can equal or overcome gravity. Apply these facts in a class discussion of the reasons why the planets and their satellites neither fall into their primaries nor go flying off into space (Ref: 2, Chap. IV; 12, p. 25; 18, p. 91; 19, Chap. 48.)

*3. Construct a chart or poster showing the relative sizes of the planets. (If pupils are able to work with proportions, let them figure out their own scale from the actual sizes of the planets; if not, many of the references

provide appropriate figures.) (Ref: 1, p. 14; 2, p.220; 11, pp. 24-26; 12, Chap.III; 14, p.123; 18, p. 13; 20, entire book.)

4. Start a class discussion on the problem of finding the length of a planet's day. Apply the observation methods decided upon to the cases of the moon, Mercury, Venus, and Mars, pointing out why the length of Venus' day remains unknown, and explaining how the moon can keep one side constantly toward the earth and yet have alternate day and night at every point. The more clearly the pupils come to picturing their own earth as an object rotating in exactly the same fashion as the other planets, the better; let them see the problem of measuring the earth's day from some other planet (Ref: 2, pp.178,189; 12, pp.89, 118, 122; 19, Chap.19.)

*5. Some burning glasses and small blocks of wood, parrafin, and metal will be available in the classroom. Experiment with these, to find out how much heat you can get with the glasses. Where does the heat come from in the first place? Could you do the same thing with the light from the moon? From a star? What is the reason? (Ref: 2, p.297, Chap. VIII.)

*6. Cut a round hole the size of a penny in a piece of paper or cardboard, and hold it up so the sun can shine through it. Let the round beam of sunlight shine through the glass prism you will find on the apparatus table. What hap-

pens to the beam of sunlight? You can tell better if you let it fall on a piece of white paper (Ref: 2, Chap.VII; 9, Chap. V; 12, p.99; 19, Chap.49.)

Repeat the experiment, with a very narrow slit instead of a round hole to shape your beam of sunlight. What is the reason for the difference? (Ref: Same as above.)

*7. Which planets would you expect to be the hottest? Which the coldest? If the temperatures of any of them have been measured, do they agree with your ideas? (Ref: 2, Chap. V; 12, Chaps.II-III; 18, Chaps.VI-VII; 19, Chaps. 18-29; 20, Entire book.)

8. Hold a class discussion on the observations of Roemer which led to the discovery of the finite speed of light, and its measurement. Most of the references given for item one contain this story at some point; the discussion should attempt to bring out some of the importance of this piece of knowledge in modern physics. The amount of detail of this nature which can be introduced depends, of course, on the level of the class. (Ref: 1, p.46-7; 2, p.63,205; 12, p.136.)

*9. Pick any one of the planets, and find out all you can about it; be prepared to tell the class as many reasons as possible why you think you could, or could not, live there. If you think <u>anything</u> can or does live there, give your reasons for this belief also. (Ref: 1, Chap.IV; 2, Chap.V; 11, Chaps.V-VI; 18, Chaps.VI-VII; 19, Chap.18-29; 20, entire

book.)

*10. You may have read in the paper some time during the last few years that a comet had been discovered, and that someone had prophesied that it would destroy the earth. Is this a new idea, or have people always been afraid of comets? If a comet actually struck the earth, what do you think would happen? (Ref: 1, Chap.XVI; 2, Chap.VI; 12, Chap.V; 18, Chap.X; 19, Chap.31.)

*11. In what ways can you tell a star from a planet, observing with the naked eye? How could you tell with a telescope? Are these distinguishing characteristics due to difference in size, distance, or something else? (Ref: 12, Chap.VII.)

*12. Sirius, apparently the brightest star in the sky, is about nine light years from us. Another star, the nearest except for the sun, is about four light years away, but can be seen only in a telescope. Can you explain this? (Ref: 2, Chap.VIII; 5, entire book; 12, Chap.VII.)

*13. The star Antares is about 360,000,000 miles in diameter. How big would it be on your poster showing the sizes of the planets and sun? (Item 3)(Ref: 18, pp.272,274; 12, pp. 346-7.)

14. Show slides or display mounted photographs of portions of the Milky Way. During discussion of these, stress carefully the fact that only a small fraction of the stars

actually present are bright enough to register on the photographs. The principal difficulty will be to get across at the same time the facts that there are a vast number of stars, yet actually they are so far apart that space may be said to be practically empty. The photographs will certainly convey the first item; but there exist few if any graphic means of impressing the second upon the human mind. The teacher must learn and appreciate the figures involved as well as possible and use verbal or pictorial illustrations such as he feels will best suit the class in question.

If the pupils have had enough intuitive geometry to appreciate at all clearly the relationships between linear dimensions and volume, the fact may be of some help; if they have been on field trips at night to study the constellations, the teacher may point out that the sky would appear much the same seen from near any of the thousands of points of light that crowd the Milky Way photographs-- that, in fact, the earth is <u>within</u> those apparently crowded star clouds, not merely viewing them from a distance. (Ref: 2, Chap.XI,XII; 5, entire book; 12, Chap.VII; 15, entire book; 17, entire book.)

*15. Compare the distance of the farthest known planet with that of the nearest known star (other than the sun). Do you think that we could see a planet circling that star with any of our present telescopes? (Ref: 2, pp.220, 308.)

16. Project or pass around mounted pictures of various star aggregations-- globular clusters such as M13 or 47 Tucanae; irregular nebulae such as the Magellanic Clouds; and spiral nebulae in various aspects such as M31 or 33, M81, NGC4565, and pictures of the first two resolved into stars. Initiate discussion on the sizes, distances, and natures of these objects, and their points of similarity to and difference from the Milky Way system. (Ref: 2, Chap.XI,XII; 3, entire book; 5, entire book; 12, Chap.VII; 15, entire book; 17, entire book.)

*17. Find a picture of some celestial object which, from your reading and discussions, you think probably resembles our Milky Way system. (Ref: 1, Chap.19; 2, Chap.XI,XII; 3, entire book; 5, entire book; 12, Chap,VII; 15, entire book; 17, entire book.)

18. Devote one or more class periods to the exhibition and explanation by their creators of optional projects, the posters, compositions, and discussions required by Items 1, 3, 5, 6, 7, 9, and 13. These as well as the other required items will, of course, have been discussed during the progress of the unit; the final discussion should serve as a summary.

19. Test.

Optional Related Activities.-- The teacher may feel that some of the following activities should be required rather

than optional. The feeling may be perfectly justified by the particular situation which may exist, and no hesitation should be felt in making whatever alterations in arrangement seem indicated.

1. Make a scrap-book of astronomical pictures, arranging them so as to tell a clear story about something you have learned in this unit.

2. Construct a set of models, in clay or plaster of Paris, of the planets in their correct relative sizes; you might also paint them to resemble the telescopic appearance of the originals, (Ref: 1, p.14; 2, p.220; 11, pp.24-26; 12, Chap.III; 14, p.123; 18, p. 13; 20, entire book.)

3. Get outdoors after dark, either with a star map or with someone who knows the constellations, and try to learn enough to be able to locate some interesting subjects for a small telescope. (Ref. 14, entire book.)

4. If there is an observatory in or near your town, get together with as many of the class as are interested and ask the teacher to arrange a trip to it some evening.

5. If your school playground is large enough, or you have access to some other fairly large plot of ground, lay out a scale model of the solar system in the open. Try to find out how far away the nearest star would be on this model. Do you see why people talk of "empty" space? (Ref. 2, pp.220, 308.)

6. Draw a circle about an inch in diameter on a piece of paper, and make a few dark spots and heavy lines inside it. Then have some of your friends try to copy this design from distances of ten to twenty-five feet.

It has been suggested that the "canals" of Mars may be an illusion caused by our inability to see clearly. After looking at the copies made by your friends, do you think this idea may be right?

7. One of the results desired from the rocket experiments at White Sands, New Mexico, is a combined observatory and laboratory circling permanently outside the earth's atmosphere. Write down all the advantages that you think such a structure would possess over our present laboratories and observatories.

8. If the school has a spectroscope, or enough material for you to improvise one, volunteer to demonstrate to the class how the yellow line of sodium vapor matches one of the black lines in the solar spectrum. (Ref: 2, Chap.VII; 9, Chap.V; 12, p.99; 19, Chap.49.)

9. If you are a Boy Scout, meet the requirements for the Astronomy Merit Badge.

10. Either by yourself or with a group of other pupils, construct a small reflecting telescope. (Ref: 21, entire book.)

11. If ideas for any other projects occur to you, get the teacher's approval and go ahead.

Optional and required reading.-- As the lists of reading materials for these units overlap very largely, they have been consolidated into a single book list at the end of the paper. The references given in the preceding assignment are to this list.

CHAPTER III

THE SECOND UNIT: THE CLOCK BENEATH OUR FEET

Statement and Delimitation of the Unit

The Unit.-- The earth, turning steadily on its way through space, forms a gigantic and extremely accurate clock. If the observer's location on the earth is known, observation of the celestial bodies passing endlessly above him forms a means of measuring time; conversely, if the time is known, such an observation helps determine the observer's position.

Delimitation.-- Some of the following statements may need to be rephrased, or even omitted entirely, for some lower classes. The teacher should feel free to perform either operation, as his particular situation requires. The matter of the date line, in particular, can be extremely confusing if a good mental picture of the entire situation has not been formed.

1. The earth rotates on its axis, independently of all its other motions, from west to east once each twenty-four hours.
2. Objects in the sky appear to travel, since we cannot perceive directly the earth's rotation, westward around the earth once each twenty-four hours, or through fifteen degrees each hour.
3. The word "meridian" is employed in two ways.

a. A meridian is any great circle passing through the earth's poles of rotation.

b. "The" meridian, referred to the sky, is the great circle passing from the north point of the horizon to the south point over the observer's position.

4. The point in the sky directly above the observer's head is called his zenith.

5. Longitude is the angular distance east or west of some standard meridian, nowadays usually that of Greenwich.

6. The difference in time between Greenwich and any other point is proportional to the difference in their longitudes; when it is noon at Greenwich, it is one hour earlier fifteen degrees further west, two hours earlier thirty degrees further west, and so on.

7. A celestial object seen on the meridian from one point on the earth will appear displaced to an observer situated in a different longitude.

8. Since the celestial bodies are either relatively motionless as seen from the earth, or have their motions well determined, they may serve as the figures of a clock of which the observer's meridian is a hand; and by measuring the position of any

standard celestial object, time may be determined.

Such measurements form part of the routine duties of certain observatories.

9. Various instruments have been used in making celestial measurements for time and navigational problems. Among those invented long ago are the sundial, cross-staff, and astrolabe; more recent devices include the sextant and transit telescope--the latter frequently equipped with photo-electric devices which measure the time of a star's meridian passage far more accurately than the eye.

10. The zeniths of two observers separated a certain number of degrees on the earth's surface are separated by the same number of degrees in the sky; consequently, simultaneous observation of the same celestial object from the two points provide data from which their separation on the earth's surface may be calculated.

11. As a consequence of statements six and ten, computing either the <u>longitude</u> or the <u>time</u> of any spot on the earth is essentially the same problem: if either is known, the other can be calculated from an astronomical observation.

12. Information about the positions of heavenly objects, together with other data needed for observation and

computation of navigational and time problems, may be obtained from the American Nautical Almanac, published yearly by the United States Naval Observatory, sold by the Superintendent of Documents, Washington, D. C.

13. The fact that the earth's orbit is not perfectly circular results in irregularities in the apparent or "sundial" time. For precision purposes a uniform time known as "mean" time is used; the difference between apparent and mean time is known as the equation of time. The value of the equation of time for each two hours of the year is given in the American Nautical Almanac; it must be used to correct time observations made from the sun.

14. Since even a slight difference in longitude means a difference in time, the world has been divided arbitrarily into zones which take their time from a standard meridian running through each zone. The time in each zone is one hour different from that in the adjacent ones. The United States covers four such zones. Almost all countries have agreed to this arrangement.

15. In computing time in each zone around the world, the certainty of passing midnight, and consequently changing date, must be considered. To minimize confusion from this cause, the International Date

Line has been adopted. It follows roughly the meridian opposite Greenwich, swerving occasionally to avoid dividing islands or groups of islands. In crossing this line in a westward direction, one day must be added to the date; crossing it in an eastward direction, one day must be subtracted.

16. In order to have Greenwich time to compare with local time for navigational purposes, ships formerly carried very accurate clocks known as chronometers. These are now supplemented by radio time signals, which are much superior.

17. For measuring very short intervals of time, astronomical observations are not adequate, and various types of clocks have been invented, such as the pendulum clock, the balance wheel clock, and various forms of electric clocks. All of these are calibrated astronomically, however, in the last analysis.

The Unit Assignment

Introduction.-- The design and presentation of material calculated to arouse pupil interest forms a worthy challenge to the teacher's ingenuity. The bulletin board forms the most obvious means of directing interest to the material of the unit, before the latter has actually started. The exhibit may be designed by the teacher or by pupils. It may

deal with sundials, hour glasses, and other means of measuring time; with astrolabes, cross staffs, sextants, and similar devices for measuring angles; or with the equipment and procedures of the Greenwich or U. S. Naval Observatories. Local events and institutions may, of course, furnish more appropriate subjects for the bulletin board than could possibly be planned in advance.

The body of the assignment.-- As in the first unit, unmarked items refer to activities conducted by, or under the direct supervision of, the teacher; items marked with an asterisk are those which would appear on the pupils' study guide.

*1. Mark the path of the shadow of some object, such as a flagpole outdoors or something in the window of the classroom indoors, during as much of the day as possible. Make the marks at regular intervals; notice the distance between them and the shape of the curve followed by the shadow. Repeat this on different days. Does the shadow reach the same point at the same time on each occasion?

*2. Find and examine a map showing the time zones of the United States. Why are the boundaries between zones not straight lines lying half way between the standard meridians? (Ref: 2,p.73.)

3. Initiate a discussion to explain the terms used in

celestial measurement; meridian, zenith, horizon (for more advanced groups, terms requiring more complex definition, such as azimuth, declination, and right ascension may of course be included.) If possible, this should be done outdoors; if not, use reference points in the classroom. The fact that no two observers have precisely the same zenith will be easier to make clear indoors. (Ref: 2, Chap.I; 6, Chap.VII; 12, pp.29-30.)

*4. St. Paul Island, in the Indian Ocean, is almost directly opposite San Angelo, Texas, on the earth globe. When the time is 8:00 A. M. at San Angelo, what time is it on St. Paul Island? (If the class is sufficiently advanced in geography, the latitude and longitude of the two points may be substituded for the first sentence.) (Ref: 2, pp.71-73; 6, Chap.IX.)

*5. El Paso is thirty degrees further west than Philadelphia. When a sun dial in El Paso reads noon, what will a sun dial in Philadelphia read? (Several problems of this type should be given, suiting the conditions to the arithmetical abilities of the class.) (Ref: 2, pp.71-73; 6, Chap.IX.)

6. Discuss the reason for the Date Line. This may consume a good deal of class time, but the time will

be well spent. (Ref: 2, p.74; 6, p.142.)

*7. An airplane leaves Hawaii at 10:00 P. M. on April 6, and flies to Tokyo. The flight takes ten hours, the plane arriving at 4:00 A.M. April 8. Explain in your own words the reason for the extra day.

*8. The captain of a ship observes the sun at his local meridian, at a time when his chronometer indicates 1510 (3:10 P.M.) Greenwich Mean Time. What is his longitude? (Correction for such matters as Equation of Time may be included or not, according to the nature of the class.) (Ref: 2, pp.71-2; 6, Chap. XII; 12, pp. 28-29.)

*9. If you were marooned on an island or lost in a large desert, what material would be absolutely necessary to enable you to find your longitude? How much of this could you make yourself? (Ref: 12, p.28-29.)

*10. In the seventeenth century a very accurate, portable clock known as the chronometer was invented. What do you imagine some of the results of this invention were, especially in connection with geography and exploration? (Ref: 12, p.29.)

*11. How many different devices for measuring time have you seen, either with your own eyes or in books? Can you think of any other ways to measure it? (For advanced classes: what scientific principles

or laws underlie the operation of these devices?) (Ref: 10, entire book.)

12. Hold an exhibition of articles and delivery of reports made or written for required and optional projects connected with this unit. Correct obvious misunderstandings shown up by this activity.
13. Possible field trips: Astronomical observatory, clock or watch factory, bridge of a ship. Include pupil reports of such trips in Item 12.
14. Test.

Optional Related Activities.-- The list of activities given below is fairly well differentiated, but may easily be augmented by the teacher who is familiar with the individual tastes and interests of his pupils.

1. Give a report to the class on the history of time measurement, from the viewpoint either of the devices or the unit systems employed. (Ref: 10, entire book.)
2. Make a chart or poster showing the meaning of some of the special terms used in this unit, such as meridian, zenith, horizon, north point, and azimuth. (Ref. 2, Chap.I, 6, Chap.VII.)
3. Read "A Tour of the World in Eighty Days" by Jules Verne. This is a good adventure story, but you must

keep very careful track of the time.

4. Make and set up a sun dial. Explain to the class any corrections which must be made in reading it during different seasons. (Ref: 10, entire book.)
5. Make an hour-glass, water clock, hour candle, or some other non-astronomical device for telling time. Explain how you made and calibrated it. (Ref: 10, entire book; most general science texts.)
6. Find the difference in longitude between your school and the standard meridian of your time zone, by finding the clock time of local apparent noon. Check your results with a map. (Don't forget the Equation of Time.) (Ref: 2, pp.71-2; 6, Chap.XII.)
7. If you or your class built a telescope for the other unit, design a clock drive for it. Why must this work at a different speed from an ordinary clock? (Ref: 2, p.68.)
8. Make a model that will show the workings of the ordinary mirror sextant. What angle is the largest that can be measured on its sixty-degree arc? (Ref: 6, Chap.VIII.)

Optional and required reading.-- This may be chosen from the book list in Chapter IV. For required reading, sections of not more than two or three books which cover the subject generally should be assigned; any available books dealing with the subject in any way should be placed on the optional list, perhaps with brief comments covering their points of applicability.

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CHAPTER IV

READING MATERIAL

Astronomical and Navigational Publications

Books.-- Since astronomy is intimately connected with all the other physical sciences and since, like the others, our knowledge of it has expanded at an almost incredible rate in the last few decades, any book on the subject will inevitably become out of date very quickly in many of its statements-- frequently between the dates of completion and publication. In teaching the first unit, therefore, books must be used with caution and every effort made to keep on hand an adequate supply of recent astronomical periodicals.

The material of the second unit is less subject to this evolution; for many years the principal changes in the field of time measurement and longitude determination consisted in refinements of observational apparatus and computational techniques almost entirely beyond the average secondary school pupil. The most recent advances in navigation have involved the development of electronic apparatus which will probably make celestial navigation obsolete, but which make no less desirable an understanding of the material given in the unit-- the physical facts upon which our geographical coordinates and time systems are based. In consequence, the

sections dealing with time to be found in most astronomical texts will be found, for the most part, useful in teaching this unit.

A list of books follows, with comments.

Book list.-- An asterisk preceding a book in the following list indicates a college-level text, principally useful for teacher reference. The others are written for pupil consumption.

References in the earlier chapters are to books on this list.

1. Allen, John S., Astronomy, Bobbs-Merrill, 1945.
Written for boys of scout age (12-15 years.) For the most part accurate, clear, and concise, with a number of good diagrams. The last chapter, however, should be avoided; the author discusses interplanetary flight with, apparently, a complete lack of basic knowledge concerning rockets. If this book is available to the pupils, the teacher should read in self-defence Willy Ley's "Rockets" (Viking Press; new edition now in preparation.)

*2. Baker, Robert H., Astronomy, van Nostrand, 1938.
A standard college text; probably still the best teacher reference available.

3. Baker, Robert H., Introducing the Constellations, Viking Press, 1937.
A descriptive book, giving methods of locating the constellations and their component stars, together with some of the mythology attached to the subject. Frequent items of descriptive astronomy are included, and there are a number of good celestial photographs.

4. Baker, Robert H., When the Stars Come Out, Viking Press, 1934.
Substantially similar to #3.

5. Bok, Bart J. and Priscilla F., The Milky Way, Blakiston, 1941.

One of the series called "The Harvard Books on Astronomy." Dr. and Mrs. Bok have written an excellent exposition of Milky Way research, Dr. Bok's specialty. The text is easy to understand, and the illustrations--mostly astronomical photographs--extremely good.

6. Bowditch, Nathaniel, The American Practical Navigator, Hydrographic Office, U. S. Navy Department (H. O. N. 9.)
The text of this volume has been revised time and again in the many years since its first appearance, to conform to current conditions. This is a standard text for students of navigation, and much of the material is too concise and technical for secondary school pupils; but many of the definitions and diagrams will be found useful. Much of the material too advanced for the pupils will form good background study for the teacher.

7. Campbell, Leon and Jacchia, Luigi, The Story of Variable Stars, Blakiston, 1941.
One of the Harvard books on astronomy, written for the layman and perfectly good for high school pupils. Photographs, diagrams and text all good: it deals with a highly important field of physical astronomy, and should help make clear to the pupil the interdependence of the physical sciences.

8. Cothren, Marion, This is the Moon, Coward-McCann, 1946.
An interesting child's book dealing with both our physical knowledge of the moon and the mythology connected with it.

9. Dimitroff, George Z. and Baker, James G., Telescopes and Accessories, Blakiston, 1945.
One of the Harvard books. Good diagrams and explanations of the various pieces of apparatus used in astronomical research.

10. Flynn, H. E. and Lund, C. B., Tick Tock, Heath, 1938.
A book for the early primary grades, telling in narative form about the various devices people have used to measure time.

11. Fontany, Elena, Other Worlds Than This, Thomas S. Rockwell Co., 1930.
A description of the other planets of the Solar System. As may be inferred from the date of publication, some of the information is a little out of date; but for the most part its avoidance of the more technical

points has saved it from this fate.

12. Harding, Arthur M., Astronomy, Garden City, 1940.
General descriptive astronomy; structure of the Solar System, nature of the stars, mythology, all intermingled. Some good diagrams and fair photographs.

13. Johnson, Gaylord, Discover the Stars, Leisure League of America, 30 Rockefeller Plaza, New York, N. Y., 1938.
A small, paper-bound booklet containing a number of very good classroom and individual experiments dealing with astronomical matters.

14. Olcott, William T., A Field Book of the Stars, Putnam, 1914.
Constellation maps arranged by seasons, with a few pages on the structure of the Solar System and Universe.

15. Parker, B.M., Beyond the Solar System, Harper, 1941.
A description of the Milky Way system and its relation to the rest of the universe, written for children in the early primary grades. Contains a number of good photographs.

16. Reed, W. Maxwell, The Stars for Sam, Harcourt, Brace and Co., 1931.
Astronomy as explained to the writer's nephew, a boy of ten or twelve years. Some of the more imaginative ideas expressed are based on outdated premises, but the book is good reading in spite of this, and the basic information is for the most part accurate.

17. Shapley, Harlow, Galaxies, Blakiston, 1943.
One of the Harvard books. Explanation of the methods of research and reasoning employed in finding out about the things which make up the limits of the known universe. Best read in conjunction with "The Milky Way" (#5). As in most of the Harvard books, the photographs are excellent.

18. Swezey, G. D. and Gable, J. H., Boy's Book of Astronomy, Dutton, 1936.
The section on the Solar System is good; there is not much on the rest of the universe.

19. Washburne, C. and F. and Reed, F., The Story of Earth and Sky, Century, 1933.

Sections on the structure and history of the earth, and nature of the universe. Rather a good general science text, except for the lack of human applications. The section on astronomy is perfectly applicable to the first unit.

20. Whipple, Fred L., Earth, Moon, and Planets, Blakiston, 1941.
One of the Harvard books; a good, clear account of the structure of the Solar system and what is known of its component bodies.

21. Ingalls, Alfred, Editor, Popular Science articles, Amateur Telescope Making.
Collected and edited into an excellent text book.

Periodicals.-- The following list gives the names, publishing organization, and address of a number of astronomical periodicals. The price, when given, is ordinarily that of a year's volume. Some club organs are distributed to members only; these are so indicated. It is a good idea for science teachers as well as interested pupils to become members of such organizations; dues are usually very small.

1. The Astronomical Journal, Dudley Observatory, Albany, N. Y. $5.00

2. Astrophysical Journal, University of Chicago Press, 5750 Ellis Ave., Chicago, Ill. $10.00 (Professional)

3. Bulletin of the Eastbay Astronomical Association, 4917 Mt. Blvd., Oakland, Calif. (Members)

4. Bulletin of the Lehigh Valley Astronomical Society, 519 Harrison St., Allentown, Pa. (Members)

5. Griffith Observer, Griffith Observatory, Los Angeles, California, $1.00.

6. Journal of the Royal Astronomical Society of Canada, 198 College St., Toronto, Ontario. $2.00

7. Journal of Calendar Reform, World Calendar Ass'n., 630 Fifth Ave., New York, N. Y. (Members)

8. Leaflets, Astronomical Society of the Pacific, Merchant's Exchange Bldg., San Francisco, Calif. (Members)

9. Monthly Evening Sky Map, Celestial Map Publishing Co., 244 Adams St., Brooklyn, N. Y. $2.00

10. News, Junior Astronomical Club, Hayden Planetarium, New York, N. Y., $.50

11. The Observer, American Astronomers of Franklin Institute, Fels Planetarium, Philadelphia, Pa. (Members)

12. The Observer, Yakima Amateur Observers, Yakima, Wash. (Members)

13. Stardust, National Capitol Astronomers, 2517 K St., N. W., Washington, D. C. (Members)

14. Popular Astronomy, Goodsell Observatory, Northfield, Minn. $4.00

15. Publications of the Astronomical Society of the Pacific, Merchant's Exchange Bldg., San Francisco, Calif. $5.00

16. Scientific American, Munn & Co., 24 W. 40th St., New York, N. Y. $4.00

17. Sky and Telescope, Harvard Observatory, Cambridge, Mass. $2.00

18. Texas Observer's Bulletin, Oscar E. Monnig, 1010 Morningside Drive, Ft. Worth, Texas. $1.00

19. Variable Comments, American Association of Variable Star Observers, Harvard Observatory, Cambridge, Mass. (Members)

Thanks are due to Dr. Charles A. Federer, editor of Sky and Telescope, who furnished and brought up to date for the writer the foregoing list of periodicals.

Numbers 5, 6, 8, 9,14,15,16, and 17 in this list will probably be found most useful in the classroom or school lib-

rary. The Astrophysical Journal is definitely a professional publication for astronomers, but the teacher with a strong science background will find it extremely useful in keeping his astronomical knowledge up to date.

Probably the most complete source of information concerning astronomical publications, both books and periodicals, is the Book Corner, Hayden Planetarium, New York, N. Y.

A Caution.-- The teacher should remember, and if necessary point out to the pupils, that new discoveries are constantly being made in astronomy; and many of these are of great influence on our understanding of the universe. If any considerable variety of references, even those listed with these units, should be available, they will certainly be found to differ among themselves on many points. When this matter comes up, attention should be called to the publication date of the books in question; and capital may be made of the situation by appointing pupil committees to investigate the periodicals for the latest information on the subject. Certainly no harm can be done to the pupils by bringing their attention to the fact that theories are always vulnerable to new data.

Attention has been called to this point because many of the better-written books at the pupil's level of comprehension are old enough to contain some outdated information. They are retained in the reference lists because the elimi-

nation of all works containing errors of this nature would leave practically nothing but college-level texts. The teacher must be able to identify and correct such items of misinformation as they arise; reminding a science teacher of the need for keeping abreast of his field or fields should be superfluous.

CHAPTER V

SUGGESTIONS FOR USING THESE SOURCE UNITS

The first step in designing teaching units is a careful listing of the needs of the particular pupils involved. These needs will vary with the grade and background of the pupils; only the teacher can judge them in the case of a specific class. A pre-test covering the material supplied in these source units should be of considerable assistance in determining these needs; unfortunately, limitations of time have prevented the development and presentation of such a test in this paper.

With the pupil needs firmly in mind, the source units should be read carefully and items which appear to meet these needs noted. If some of the needs are not met by material supplied, the book list in Chapter IV may be consulted for further information; Baker's "Astronomy" will probably be the best book for this purpose. This section of the task should receive much attention, since it will, when completed, be a statement of the teacher's specific goals for the unit.

An example of differing needs, and hence of differing goals, might be found in comparing a ninth-grade class of twenty-five or thirty pupils, in their first year of general science, with a twelfth-grade class of the same size who have had at least a year of general science, one or two years of

algebra, and a year of geomety. With the first class, the specific goals might conincide almost exactly with the delimitation of the first unit, given in Chapter II of this paper; for the second class, details of Kepler's and Newton's laws may be added, while the details of the universe beyond the Solar system may be omitted-- the picture should be clear to them already. The pre-test, of course, might give the lie to the last statement; the pupils may have completely forgotten what they learned about the Milky Way a year or two before.

With the goals definitely stated, preparation of the unit assignment may begin. The assignments of the source units should be read, and those which seem in any way useful noted. In this case, there should be no haste to discard an item; as stated it may not be applicable in the particular classroom situation in hand, but with modification it may become quite serviceable. Modification rather than elimination of items should be the principal means of adapting the material of these source units to the specific classroom situation. For example, the burning-glass experiment given in the assignment of the first unit is best adapted to the modern classroom-laboratory setup; in the old-fashioned schoolroom with fixed desks and chairs, it would have to become a demonstration given either by the teacher himself or a very small group of pupils to the remainder of the class.

The introductory material given will depend particularly

on this situation; the suggested projection of astronomical pictures obviously cannot be performed unless appropriate equipment is available. For this reason, an effort was made to make this material usable on the bulletin boards or in the form of special displays, as well as by projection.

The core materials, then, must be selected with a view both to the specific objectives listed at the beginning of the planning task, and to the classroom situation. Additions to the material supplied in the source unit assignments may be found which arise from situations peculiar to the particular community involved; a seaport town provides opportunity to study the tides, while a city high in the mountains is likely to have observatory facilities not too far away. In this connection, many amateur astronomers possess excellent instruments and are more than willing to demonstrate their use to interested parties.

The preceding paragraph applies with even more force to the optional related activities. The teacher familiar with his community will almost certainly be able to add materially to the list of activities suggested in this paper. These activities, the teacher must remember, are one of the principal means of caring for individual differences in interest and ability; they should therefore cover as wide a range as possible both of difficulty and type of activity-- some should involve primarily reading, some writing or composition, some

actual construction of articles; and in each of these departments tasks of differing degrees of difficulty must be represented.

The final test should be objective in form. As in the case of the pre-test, time has prevented the inclusion of such an instrument in this paper; the teacher should not on that account neglect the task of developing one for himself. It is as true in general science as in any other field that teaching on top of imperfectly understood material is a waste of time; and the test, by its very definition, is our means of determining the degree to which the pupils have understood the unit.

It should be clear from this chapter that the source unit is not a teaching unit designed for general applicability, but a body of information from which material for teaching units may be taken. The writer hopes that, bearing this statement in mind, the general science teacher who makes use of these source units will find them of material assistance in his work.

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